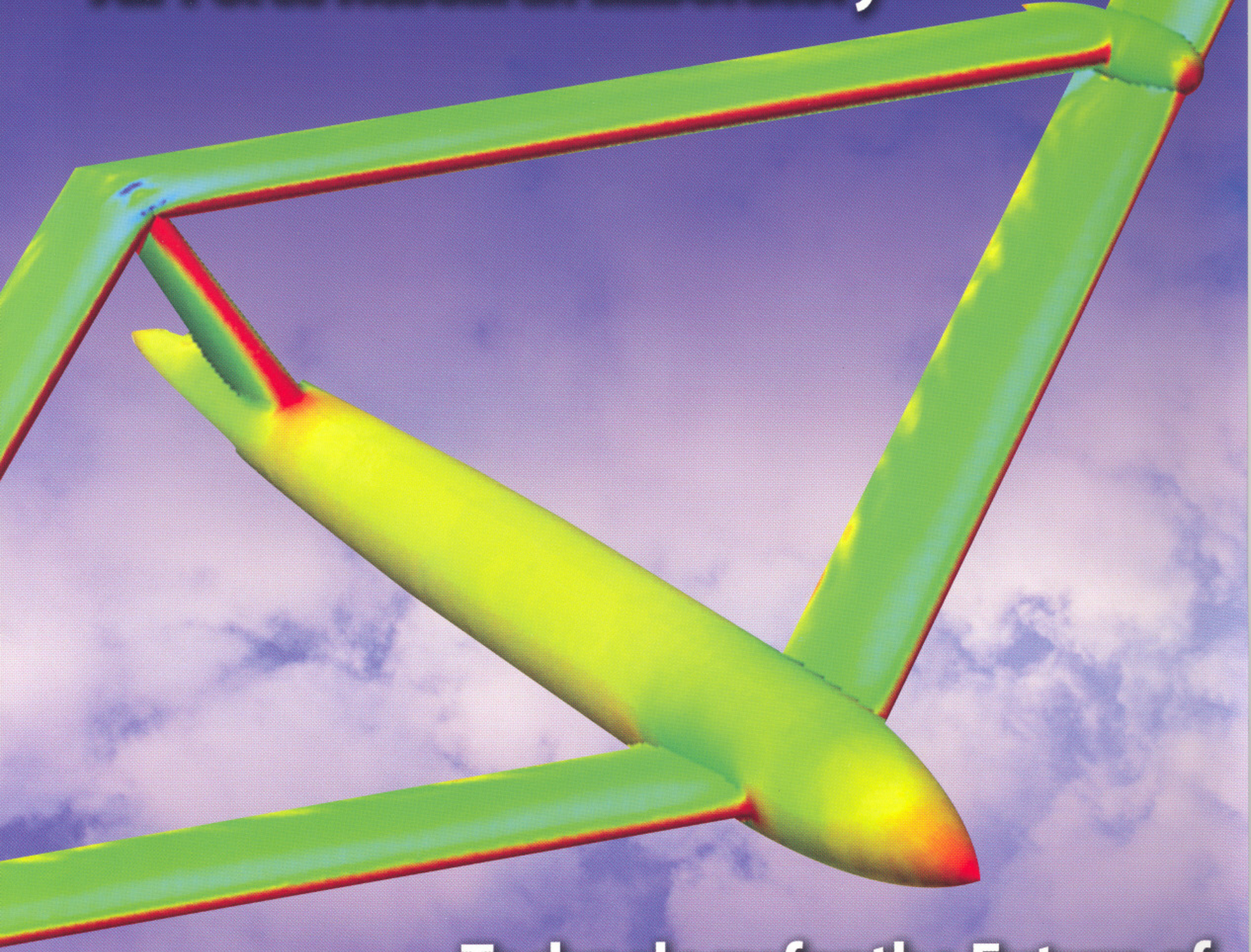
Computational Sciences Center of Excellence

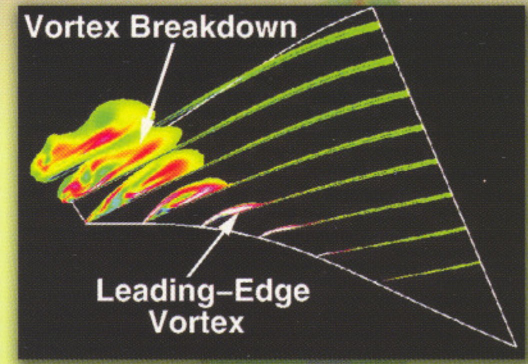
Air Vehicles Directorate
Air Force Research Laboratory



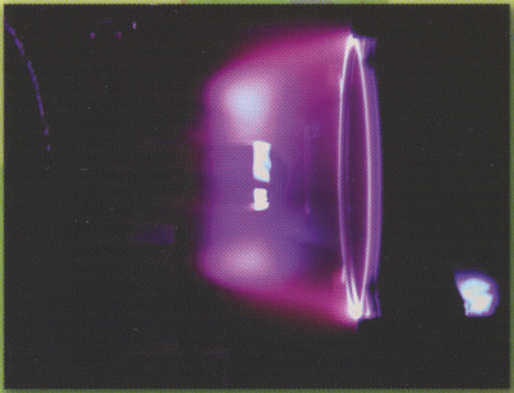
Technology for the Future of Aerospace Design and Analysis

Challenges in Computational Research

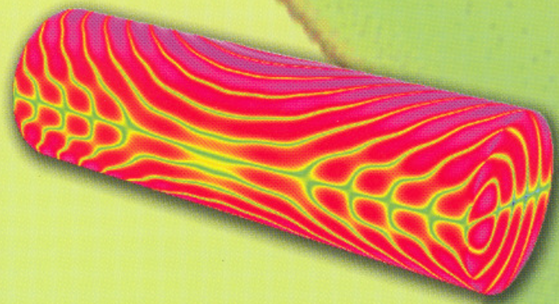
Multidisciplinary Computational Simulation
- Direct Numerical and Large Eddy Simulation
- Non-Linear Fluid/Structures Interaction
- High-Order Algorithms
- Overset Structured-Grid Algorithms



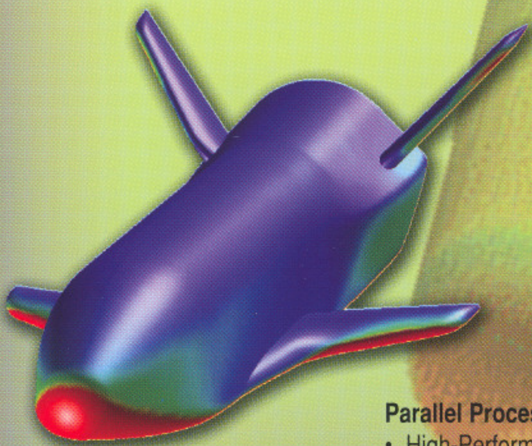
High-Speed Computational Fluid Dynamics
- Magneto-Gas Dynamics
- Non-Equilibrium Chemical/Thermal Effects
- Shock-Shock, Shock-Boundary Layer Interactions
- Validation Experiments

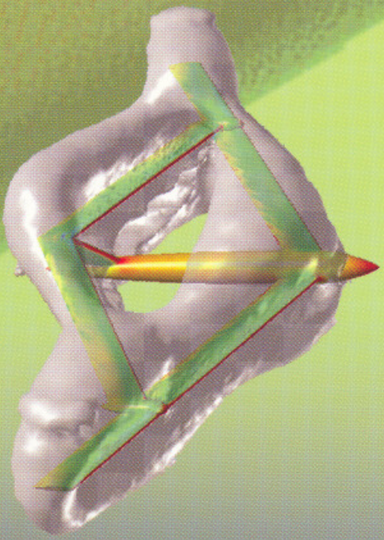


Computational Electromagnetics
- Radar Cross-Section Prediction
- Antenna Analysis



Applied Computational Fluid Dynamics
- Accurate, Robust, Efficient Reynolds-Averaged Navier-Stokes
- Unstructured Grid Generation
- Adaptive Meshes



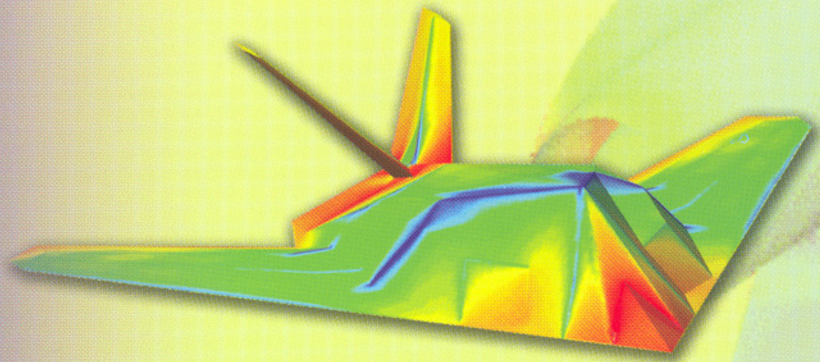


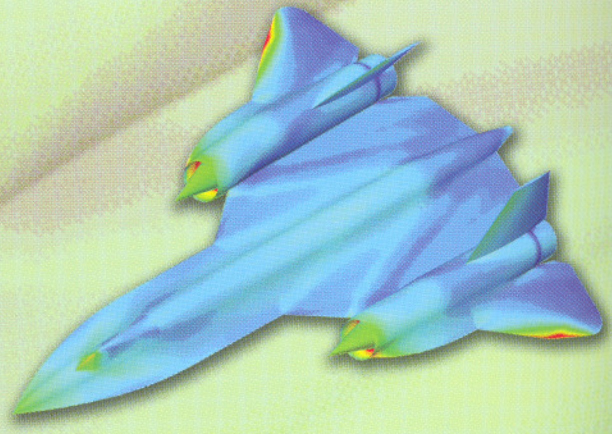
Parallel Processing
- High-Performance Computing
- Linux Cluster Computing

Computational Research for Aerospace Vehicles

The Air Force Research Laboratory (AFRL) is one of the largest complexes in the world dedicated to scientific and engineering excellence. The AFRL Air Vehicles Directorate (VA) is responsible for the development, integration and implementation of many aerospace technologies - aerodynamics, structural dynamics, flight controls, performance - for air superiority. The Computational Sciences Center of Excellence (AFRL/VAAC) develops and employs the most advanced numerical procedures for design and analysis of affordable, revolutionary technologies to sustain and extend USAF superiority.

Three primary computational sciences groups exist in AFRL/VAAC. Our first two groups focus on basic research in fluid physics, aeroelastics, electromagnetics and magneto-gas dynamics. Our third team focuses on innovative development and practical applications of robust computational aerodynamics. Together we lead the development of physics-based computational tools and techniques that enable highly efficient, accurate and affordable solutions to our customers - from vehicle designers to warfighters.





Computational Methods for Design & Analysis

Cobalt$_{60}$

Our parallel, implicit, unstructured-grid, Navier-Stokes solver. Its cell-centered, finite-volume formulation handles grids consisting of arbitrary polyhedral elements. Its parallel implementation enables computational aerodynamic solutions on nearly any platform, for any number of available CPU's. Extensions are underway to incorporate finite-rate chemistry capabilities.

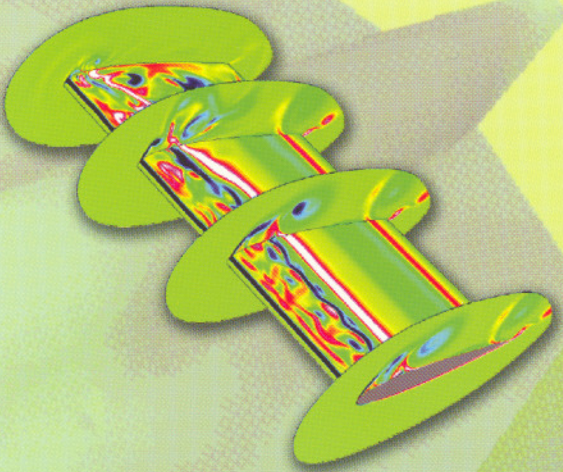
FDL3DI

Our parallel, implicit, overset structured-grid, Navier-Stokes solver. It has options for upwind-biased and highly-accurate 6th-order compact schemes. Its multidisciplinary uses include aeroelastics, acoustics, large eddy simulations, chemical kinetics and magneto-gas dynamics.

Computational Sciences Highlights

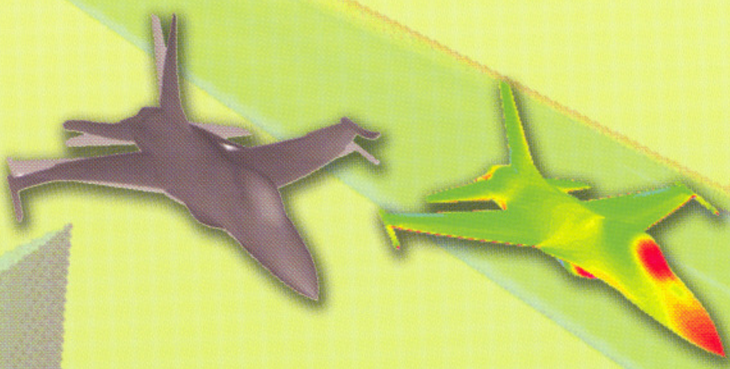
Unsteady Separation on Pitching Wing

A wing rapidly pitched beyond its static-stall angle encounters a dynamic stall event that temporarily increases aerodynamic lift. Unsteady computational results can enable detailed investigation of the flow phenomena creating dynamic stall. Our ***FDL3DI*** method, incorporating overset structured-grid methodology and parallel processing, is able to determine the performance benefits of such cases.



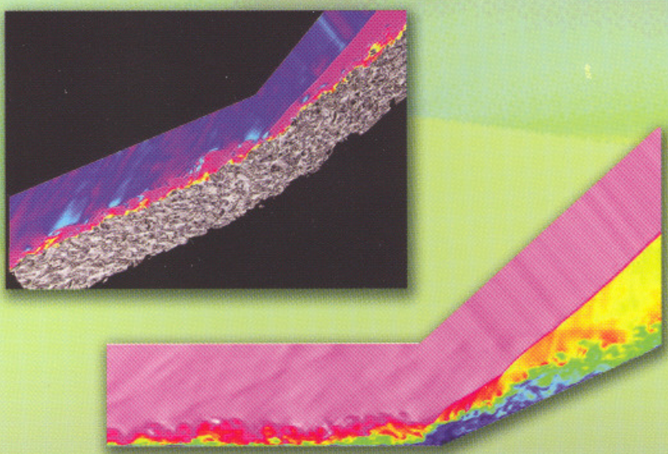
Transonic Aeroelastic Simulation

Simulations have great potential to reduce the high costs and risks associated with testing of complex fluids-structures interactions. Computational aeroelastic capability includes the effects of aerodynamics, structural dynamics, data interpolation and deforming overset grids in a coupled manner. The prediction of flutter onset for a full aircraft is a major accomplishment toward realizing the savings of reducing flight tests.



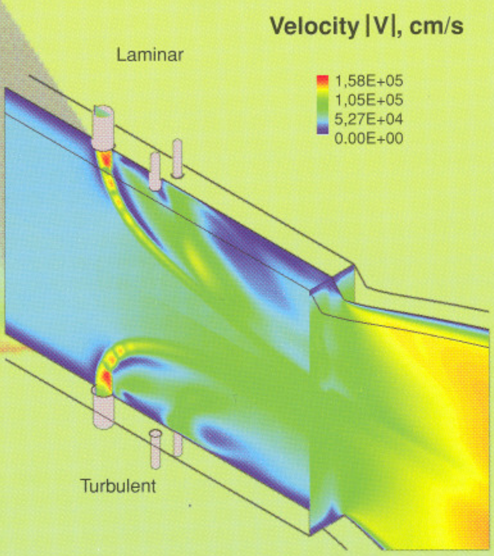
Large-Eddy Simulations

High-order compact differencing algorithms are developed for accurate simulations of turbulent, compressible flows. Large-eddy simulations of turbulence are used to remove the limitations of conventional models. As illustrated, the computational method is able to predict the complex interactions between free-stream, turbulent and shock regions.



Chemical Oxygen Iodine Laser Flowfields

Simulations of 2-D and 3-D chemically reacting flows are performed with our ***Cobalt$_{60}$*** solver including strong coupling of the species continuity equations. The illustration depicts high-speed flow through a nozzle with transverse injection of a gaseous mixture. This capability is critical to the design and analysis of industrial and military chemical oxygen/iodine laser devices.



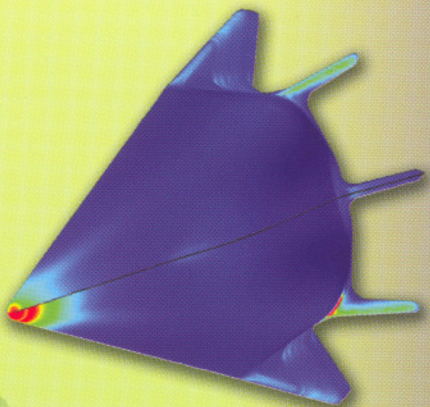
Computational Sciences Highlights

High-Temperature Gas Dynamics

Hypersonic flight and rapid space-access initiatives necessarily require consideration of high-temperature environments in thermo-chemical non-equilibrium. The difficulty of ground-testing under these conditions places a crucial emphasis on modeling and simulation techniques that accurately predict molecular kinetics at the quantum level. The Master Equation is solved numerically to reproduce the coupling of vibration, rotation, translation and their effects on dissociation. Results are yielding improved accuracy in predicting engineering applications of vehicle shock stand-off, heat transfer, and dissociation rates.

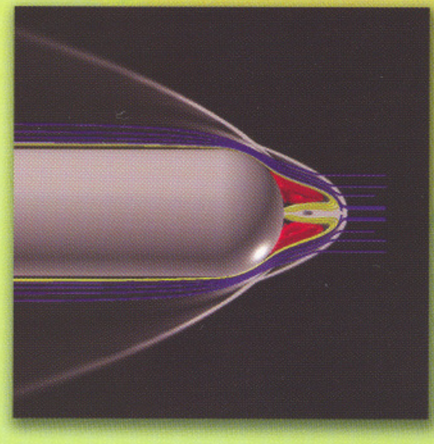
Magneto-Gas Dynamic Control of High-Speed Flows

Techniques utilizing synergistic interactions between electromagnetic and fluid dynamic forces have the potential to revolutionize flight at speeds higher than 5 times that of sound. Electromagnetic forces can considerably reduce drag and heat transfer, provide critical propulsion efficiency improvement, and enable high-enthalpy wind tunnel development. High-fidelity simulation tools are being developed which combine the Navier-Stokes and Maxwell equations to investigate the phenomena, with emphasis on extreme aerospace environments. Simulations have explored the basic mechanisms, while current focus is on electromagnetic flow control.



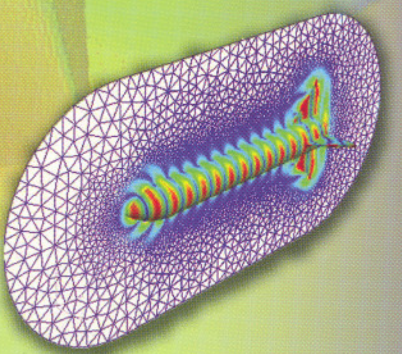
Counterflow Drag Reduction

Injection of plasma or high-temperature gas from the nose of a forebody is simulated and compared with experiments. A sudden change, called bifurcation, of the dynamic state from oscillatory to nearly steady motion depends on the stagnation pressure of the counterflow jet. Promising results indicate that the aerodynamic drag on a hemispherical nose/cylinder at Mach-6 can be reduced by as much as 40% at the bifurcation condition.



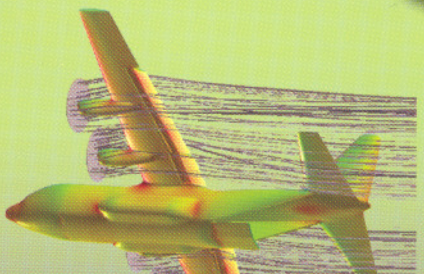
Computational Electromagnetics

Methodology developed and applied in computational fluid dynamics is extended to the solution of the Maxwell equations. Finite-volume, time-domain formulations are being applied in both structured and unstructured grid techniques. Parallel computing capability has further improved the effectiveness of simulating dynamic and wide-band electromagnetic phenomena.

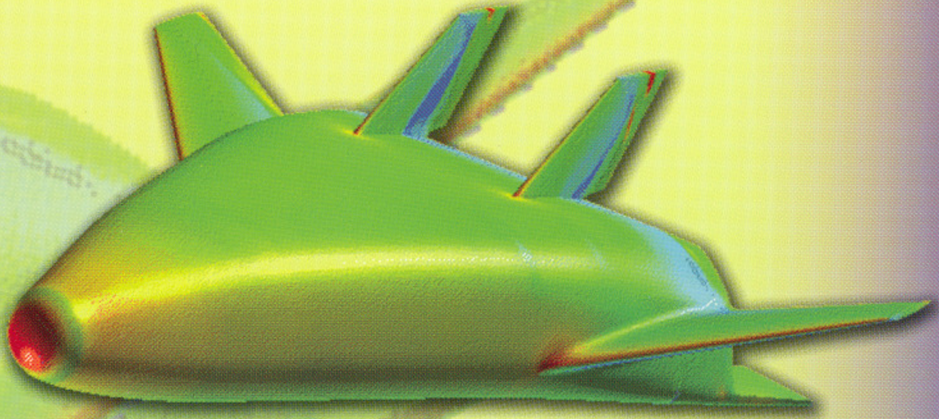


Applied Computational Aerodynamics

Computational fluid dynamics methods based on unstructured grids play an ever-increasing role in engineering design and analysis. Our ***Cobalt***$_{60}$ solver is used routinely to acquire transonic, turbulent results in relatively short turnaround times. Typical configurations are very complex with tens of millions of grid cells. Parallel processing and adaptive meshing techniques are key emphasis areas to further enable accurate, affordable aerodynamic design and analysis capability.



Computational Research for Aerospace Vehicles



Our Commitment

As missions for aerospace vehicles become more difficult and demanding, the role of computational-based methods becomes increasingly important. We are advancing the state-of-the-art by improving our understanding and by developing faster, more accurate and easier-to-use techniques. In so doing, we are committed to assuring the technical superiority and affordability of our vehicles keeping us the best Air Force in the world.

How to Contact Us

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